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The Work Required to Operate Several Makes of Typewriters

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This paper reports a series of carefully conducted tests made on five standard typewriters, manufactured by different companies and bought at retail stores, to determine the amount of work required for their operation.

To eliminate the human element and to make it possible to measure the work involved, the typewriters were operated pneumatically by a specially designed apparatus which also recorded on a photographic film a curve whose integrated area was proportional to the work. After mechanical operation had been adjusted so that it simulated satisfactorily manual operation, and after a careful calibration of the instruments and apparatus, tests were conducted on the operation of the following parts: the type keys, space bar, capital shift, line space, and carriage return. Tables of results show that a given typewriter may be superior to others, from the point of view of work required for operation, for one of these operations, and inferior to some other for another operation.

In order to interpret these results in combination, all of these five operations being necessary in varying degree in ordinary operation, 25 typical business letters were analyzed to determine the average number of times each operation was performed. It was then possible to determine the total work to type the average letter on each of the typewriters, and a table of these results is given.

In a summary of the results, it is pointed out that certain elements which are independent of the actual work of operating the typewriter but which seriously affect fatigue are not covered by the investigation. Recommendations are made as to adjustment and servicing of typewriters.

The purpose of this investigation was the careful measurement of the amount of work required to operate various makes of typewriters. More specifically it was desired to find the work expended in the normal operation of the type keys, space bar, capital shift, line space, and carriage return for several machines of each make; to find the average number of times each of these operations occurred in a representative business letter; and from these figures to compute the amount of work required to type the average letter on each make of machine.

Selection of the Typewriters

The typewriters used in this investigation were of five standard American makes. They were purchased with cash and without previous notice from their respective agencies in several different cities, and were carefully transported by automobile to Cambridge. The agents had no way of knowing that these machines were being purchased for the purpose of tests.

All of the machines were stated by the venders to be new machines, properly adjusted. No adjustments or alterations of any kind were made on the machines after purchase. The substitution of the special uniform platens for the regular platens was only made after all other measurements on type keys, space bar, capital shift, line space, and carriage return had been made. One make of machine regularly has supplied interchangeable platens of varying hardness. In this case the platen was selected which had a hardness nearest the mean of those supplied for the other makes. Throughout this report the makes of typewriters will be known as A, B, C, D, and E.

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Work Required by Type Keys

The precise determination of the work expended in operating a key is a rather difficult problem because the motion is rapid and the light moving parts must have no appreciable mass added to them. There seemed to be no possibility of constructing a sufficiently light recording pressure dynamometer for attachment to the key. The only possible method appeared to be rather complicated but fundamentally sound. This consisted of measuring the motion of the key when a typist operated it in the usual manner; and then constructing a mechanism which would reproduce this motion and at the same time record the pressure exerted throughout the stroke. As the movement of the key is the same in both cases, the work performed by the typist in pressing the key must be equivalent to the mean effective pressure measured during the similar mechanical stroke, multiplied by the length of the stroke.

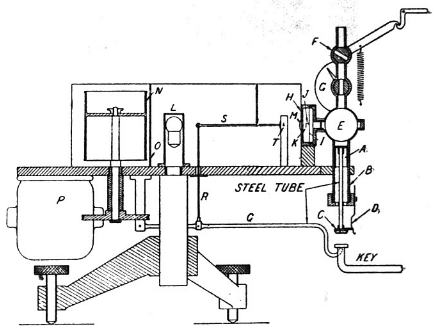


Fig. 1 Apparatus for Operating Type Keys

Description of the Apparatus

The apparatus constructed for operating the key is shown in Fig. 1. The piston A sliding in the cylinder B operates through a piston rod, the felt covered disk C which depresses the typewriter key. This disk can be initially held at any fixed height above the key by the stop D which is so delicately adjusted as to offer practically no resistance to the piston movement. The piston was carefully lapped into the cylinder and an oil seal was provided by several narrow grooves cut around the piston. All the moving parts were kept very light so that their mass would be a small fraction of the mass of the key and its attached mechanism.

The piston is operated by admitting compressed air into the reservoir E above the cylinder. In order that air should be introduced into the reservoir suddenly and in exactly the same way under like conditions, the spring-operated valve F is used. This stopcock is held shut with a trigger and opened suddenly by a strong spring. In addition there is a graduated throttle valve G to vary the rate at which air is introduced.

Connected directly to the reservoir by a short and relatively large passage (to eliminate any distortion of the pressure wave) is the high-frequency manometer *H*. This instrument is similar to the manometers used for pressure-distribution work on airplanes and airships. It has a natural frequency of about 300 vibrations per second, a constant calibration, a small temperature coefficient, and is not affected by vibration. The manometer consists of the diaphragm *I* with the stylus *J* attached to the center. The hardened tip of the stylus rests against the back of the stainless-steel mirror *K* which is mounted on pivots and held against the stylus by a watch hairspring. Therefore a slight movement of the diaphragm gives a considerable rotation to the mirror. Adjustments are provided for readily changing the zero setting or the sensitivity.

Light from the lamp bulb *L* passes through the lens *M* on to the mirror *K* and is reflected back through the same lens and

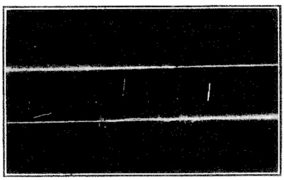


Fig. 2 Pressure Curves

focused on the film *N*. A slit *O* gives a point image on the film. The film, which is wound on a drum, is moved at a constant angular velocity by the motor *P* through suitable reduction gearing.

This instrument makes records of the size shown in Fig. 2. The range of pressure as adjusted for this work is about 50 cm. of mercury. The recorded trace is so sharp that the record can be

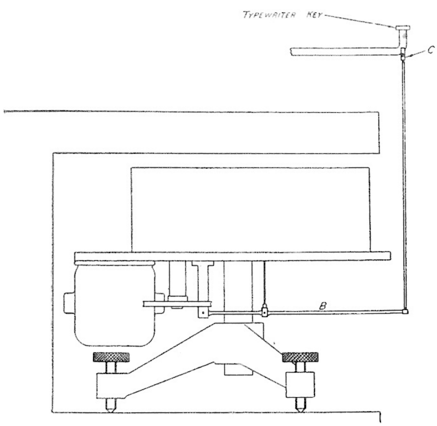


Fig. 3 Apparatus for Measuring Key Deflection

enlarged and read with much greater precision than is required here.

The movement of the key is recorded by a mechanism also shown in Fig. 1. The lever *Q* rests underneath the key and is pivoted at the back end. The link *R* connects it to a second lever *S* pivoted at *T*. On this pivot and behind a lens is a small mirror which reflects light from the lamp *L* on to the film. This allows the simultaneous recording of pressure and deflection.

When it is desired to record the key motion under manual operation, the set-up in Fig. 3 is used. The instrument previously described is placed upon a solid support under and at one side of the typewriter. A light strut *A* connects the lever *B* with the key through the fitting *C*. A record can be taken of the motion of any key, and the operator need not know which key is connected.

The air pressure supplied to the instrument is obtained from a tank of about 6 cu. ft. capacity which may be pumped up with a

Fig. 4 Assembly for Obtaining Operator's Curve

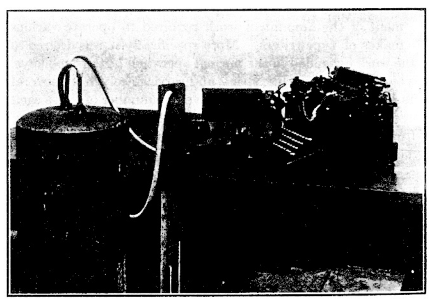


Fig. 5 Assembly for Duplication of Operator's Curve

tire pump. The tank pressure is measured by a mercury manometer in the usual way. The system was tight enough to hold a substantially constant pressure for several days.

Calibration of Apparatus

The recording manometer on the instrument was calibrated by connecting it directly to the tank and taking a number of records with several known and constant tank pressures. The film records were measured and the distance of each recorded pressure line above the zero was plotted against the tank pressures.

It should be mentioned here that all of the films were measured by placing them in a projection lantern and tracing them off to a

large but constant scale on a sheet of paper. This method was rapid and saved eye strain, which was important when it is considered that more than 2000 records were taken in developing the apparatus.

The record of the key deflection was standardized by depressing the key with a micrometer screw and taking records at frequent intervals. The resultant curve of key deflection plotted against the motion of the spot of light across the film was a straight line. This gives a constant factor by which to multiply the distance on the film in order to get the key travel. This factor was 1.24 for the short lever of Fig. 1, and 1.20 for the long lever of Fig. 3.

Figs. 4, 5, and 6 show general views of the apparatus and give a good idea of the construction and method of operation.

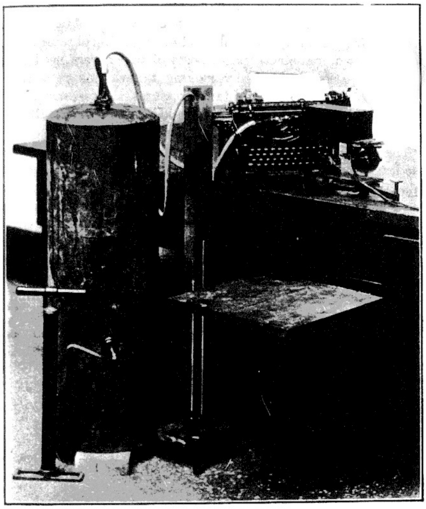


FIG. 6 ASSEMBLY FOR OBTAINING IMPRESSION TESTS

KEY MOTION WITH MANUAL OPERATION

A large number of records were made to show the key motion. These records brought out the following facts:

(a) A given operator does not exactly duplicate the record on successive trials.

(b) There is no great difference between records made by the several typists.

A number of operator's type-key-displacement records are shown in Fig. 7 to illustrate the points. From many data of this kind it was thought permissible to use the same skilled typist on all makes of machines, as this procedure in the end would give more strictly comparable results.

KEY MOTION WITH MECHANICAL OPERATION

The next problem was to so adjust the pressure cylinder as to reproduce the preceding key motions. The following adjustments could be made:

(a) Air pressure
(b) Throttle-valve position
(c) Initial height of the pad above the key
(d) Softness of the pad
(e) Lower limit of piston travel
(f) Mass of the moving parts.

It is believed unnecessary to go into the details of the adjustments made. After some experimenting practically any hand operator's curve could be reproduced. An example is shown in Fig. 8. It was shown later that a considerable change in the shape of the curve for a given tank pressure will have little effect on the type impression on the paper.

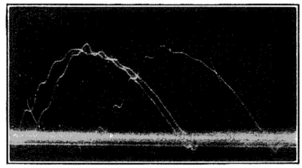


FIG. 7a

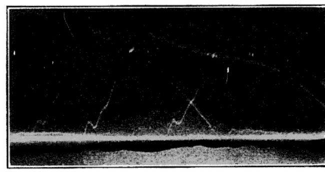


FIG. 7b

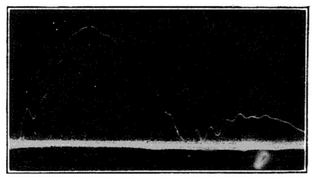


FIG. 7c

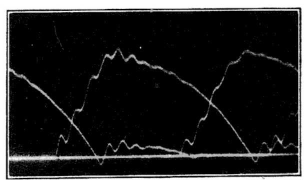


FIG. 7d

FIGS. 7a AND 7b TWO OPERATORS ON THE SAME MACHINE AND SAME KEY

FIGS. 7c AND 7d SINGLE OPERATOR ON HARD AND EASY ACTION

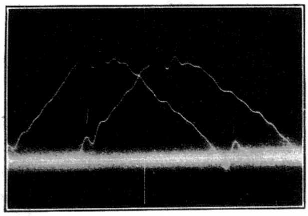
Now that it is certain that the manual motion of the key can be reproduced mechanically, the pressure curves taken simultaneously with the displacement curves are of chief importance.

In Fig. 9 are shown simultaneous pressure and displacement curves redrawn from the original of a typical record, to give a larger scale. It will be noted that the pressure rises very rap-

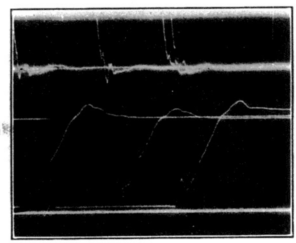
idly—in 0.0005 sec.—and, except for a slight surging on reaching the maximum, remains constant for the remainder of the stroke.

The work accomplished during the stroke is evidently equal to the mean effective pressure during the stroke multiplied by the length of the stroke and the piston area. This is the same condition occurring in engines and needs no further explanation. We have only to define the stroke and mean effective pressure.

Referring to Fig. 9, the stroke is given as the distance L, and the time by t, and the mean effective pressure by the shaded area divided by t. As the pressure on the piston is equal to the tank pressure for much of the stroke, it might be expected, that there would be a constant relation between the tank pressure and the mean effective pressure. Could this relation be established, a great deal of time would be saved as a pressure record would not have to be taken and measured for each stroke.



Mechanical



Manual

FIG. 8 REPRODUCTION OF OPERATOR'S CURVES

(The difference in height of curves is due to difference in length of magnification arm of the instrument. The oscillation shown in all curves is due to the elasticity of the key levers.)

A number of records were made on the easiest- and hardest-working machines at different pressures with the instrument assembled for operating keys, space bar, capital shift, line space, and carriage return. The mean effective pressure for each case was computed from the planimetered area under the pressure curve. The mean effective pressure thus found is plotted against the corresponding tank pressure in Fig. 10. As expected, the points fall closely on a straight line up to a pressure of 35 centimeters of mercury. Above this the points depart sharply from the line which is undoubtedly caused by the forcing of the oil out of the piston grooves at this pressure. This is confirmed by the commencement of hissing when the pressure reaches this value. The use of a heavier oil would raise this critical pressure, but as it is above the range used in these tests no change was deemed necessary.

The slope of the curve in Fig. 10 gives the factor by which to multiply the tank pressure in order to obtain the mean effective pressure. The work is given by

$$W = APKdgL$$

where

W = work in ergs
A = piston area, here = 1.292 sq. cm.
P = tank pressure in cm. of mercury
K = constant to convert tank pressure to mean effective pressure = 0.97
d = density of mercury = 13.6 grams per cc.
g = acceleration of gravity = 980 cm. per sec.
L = length of the stroke in cm.

COMPARISON OF THE IMPRESSIONS

Now that it is possible to obtain the work for a given key stroke, it is necessary to be able to duplicate the effectiveness of the stroke on all machines. This was done by using in all tests pieces of ribbon from a lightly inked ribbon 144 yards long obtained from a well-known manufacturer. Sheets of paper were used from the same package. Then by making typewritten records on each machine at a number of tank pressures, the pressure giving the nearest approach to a standard could be selected. In all such impression tests two carbon copies were made.

The selection of the tank pressures giving equal impressions is the least precise part of this investigation. By carefully examining the impressions of a number of letters in the standard and on the test sheet with a magnifying glass, two independent observers are almost always able to check each other within a pressure of one centimeter of mercury. It does not seem possible to obtain a greater precision than this because of irregularities in type, paper, and ribbon, and because of the uncertainty of matching impressions by the eye. However, this gives a precision of from 3 to 5 per cent for a single machine.

It was believed that the hardness of the platens might vary between the different makes of machines and partially account for the differences in work required to make a standard impression. A hard platen would undoubtedly require less work to produce a given impression than a soft platen. After all other tests had been completed on the machines, special uniform rolls, made up by turning about 2 mm. from the diameter of the regular platen and forcing on a brass tube of the original diameter, were substituted for the regular platens. The pressure was determined that would give a standard impression. In all cases the pressures were lower, but the comparison was made difficult because of the irregularity of the impressions made on the special uniform platen.

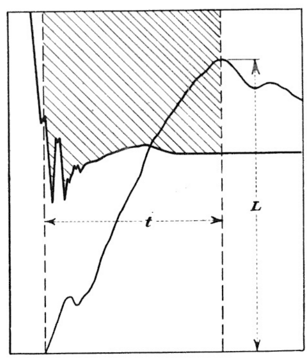


FIG. 9 ENLARGED PRESSURE-DISPLACEMENT RECORD

Method of Making Tests on Type Keys

Each typewriter was tested by placing the air cylinder directly over the key and raising the piston to the proper height. Two carbons and three sheets of paper were placed in the machine. The tank was pumped up to the desired pressure, the trigger released, and the impression made. This procedure was repeated for all the letters across the second row from the bottom, at the same tank pressure. The tank pressure was then raised 1 cm. and another row of impressions made. These impressions were then compared with the standard in the manner previously described.

Results on Type Keys

The results obtained for the type keys of the twenty-five machines tested are listed in Table 1.

On examining these results it will be noticed that there is a considerable variation in work between different makes of typewriters and a smaller variation between machines of the same make. While it is not within the scope of this report to analyze the motion of the typewriter mechanism, it is believed that most of this variation is due to the resistance offered by the carriage escapement. In fact, a small adjustment of the escapement spring will greatly alter the work required to operate the key.

In general the special uniform platen required about 0.7 of the work needed to give the same impression on the standard rubber platen.

The order of merit of the various machines in regard to typekey work is E, A, C, D, and B.

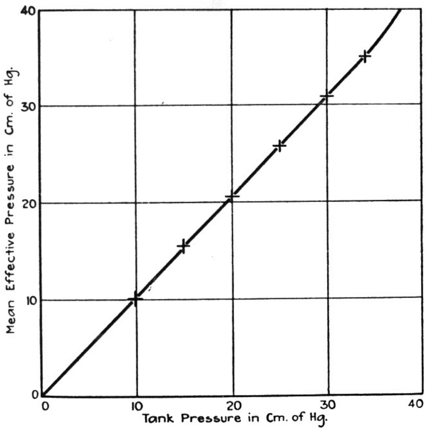


Fig. 10 Relation Between Mean Effective Pressure and Tank Pressure

It was also noticed that there is some variation in length of stroke. It should be kept in mind that the relative work required to operate the keys may not be a measure of the fatigue suffered by a typist. That is, of two machines requiring the same work, the one with a long, easy stroke might be less fatiguing than the one with a short stroke.

Work Required by Space Bar

The method of obtaining the work necessary to operate the space bar was somewhat different from that used for the type keys because no impressions are made. The method finally used consisted in obtaining typical displacement curves for the space key on each make of typewriter when operated by a skilled typist. Displacement curves were then taken when the key was operated pneumatically, at several tank pressures. A curve was then plotted of tank pressure against the time taken for the stroke as measured from the enlarged curve in the way previously described. The pressure on this curve corresponding to the time taken for the stroke by the typist was the desired value. Curves of this kind are shown in Fig. 11.

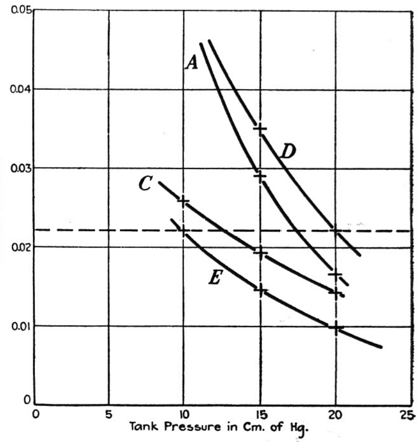


Fig. 11 Space-Bar Time Curves

The apparatus was the same as used for the type keys, but the operating pressure was considerably less.

Space-Bar Motion

In Figs. 12*a* and 12*b* are shown several pressure-displacement curves for the space bar. They differ from the type-key records in having a shorter stroke and a definite stop. The average time required for the stroke was 0.0223 sec.

TABLE 1 WORK PER STROKE[1]

Make	Type keys: Rubber platen	Type keys: Special uniform platen	Space bar	Capital shift	Line space	Carriage return
	55	40	37	147	410	1100
	43	31	47	162	550	1590
A	45	38	52	124	620	1310
	45	35	51	141	600	1340
	50	38	34	131	[illegible]	1370
Average	47.6	36.4	44.2	141.0	554	1280
	102	60	26	212	400	1430
	69	54	21	131	310	1530
B	57	42	26	137	330	1320
	76	45	21	122	370	1600
	76	54	24	164	440	1210
Average	76.0	51.0	23.6	153.0	370	1420
	76	48	23	104	460	990
	57	42	23	95	300	1430
C	57	48	30	78	480	1660
	54	40	42	106	550	1230
	57	45	30	106	550	1400
Average	60.2	44.6	29.4	98.0	468	1340
	76	54	37	147	270	1320
	59	42	26	107	190	1370
D	62	39	39	95	290	1580
	66	45	28	95	390	1540
	57	45	37	89	280	1620
Average	63.2	44.0	32.4	107.0	286	1490
	40	36	13	94	360	1020
	45	36	21	94	300	1100
E	40	32	22	106	520	1270
	48	39	25	106	540	1090
	38	31	23	135	480	1260
Average	42.2	34.8	20.8	107	440	1150

[1] The work is expressed in ergs divided by 10,000.

As the same piston was used for the space bar and type keys, the same factor for converting the tank pressure to mean effective pressure was required. The work, as before, is calculated from the same equation as the type-key work.

Results on the Space Bar

The results for the machines tested are given in Table 1.

The values of the work required by the space bars are about one-half of those for the type keys, due to the shorter stroke and lower resistance. It appears that there is little relation between the type-key and the space-bar work. For example, the machine which has the next to the lowest value for the type-key work had distinctly the greatest value for the space-bar work.

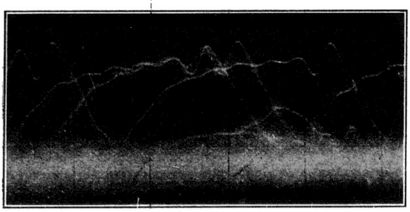


Fig. 12*a* Operator's Records of Space Bar

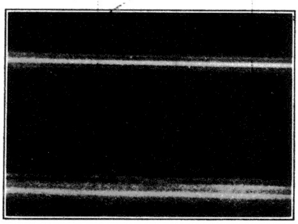


Fig. 12*b* Pressure-Operated Records of Space Bar

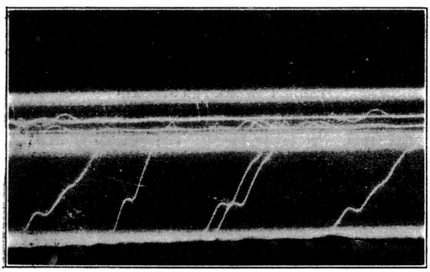


Fig. 13 Shift-Key Pressure-Displacement Records

The makes of machines may be rated in order of merit in regard to the work required by the space bar as follows: E, B, C, D, and A.

Work Required to Operate Capital Shift

The force required to operate the capital shift was so much greater than that for the other keys that a pressure of 50 to 60 cm. of mercury was needed. A pressure of this magnitude blows the oil from the piston rings and causes a bad leak. For this reason a new cylinder and piston were constructed of twice the diameter of the previous one, but in all other respects the same.

The method of obtaining the work was identical with that used for the space bar. In Fig. 13 are shown a number of pressure-displacement records for the shift key. The time of stroke is comparatively long, averaging 0.067 sec. The lengthened time is due to the large mass that must be moved.

The work required to operate the shift key on the machine is given in Table 1. The work is computed from the same equation as for the space bar, in this case the area A being 5.08 sq. cm. instead of 1.292 sq. cm. The constant K is 0.97 as before, measurements having been made of planimetered pressure curves to determine this value.

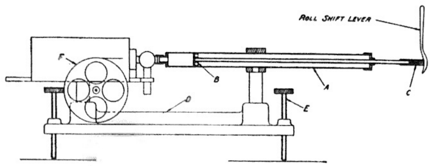


Fig. 14 Apparatus for Operation of Roll and Carriage

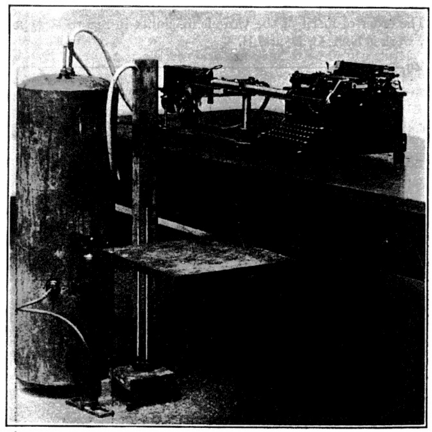


Fig. 15 Apparatus for Moving Line Space

The work required to operate the shift key is about three times as great as for the type key. There is about the same variation between machines as for the type keys. The order of merit is: C, E, and D the same, A, B.

Work Required to Operate Line Space

The method of obtaining the work required to operate the roll was the same as used for the capital shift; the operator's time was reproduced mechanically and the work computed from the pressure and the stroke. The work was obtained for moving the roll a single space as this is used probably as much as a double space in letters, and serves as a simple comparison between machines.

The apparatus used for this test is shown in Figs. 14 and 15. The same air chamber, valves, and recording manometer are used as before, but a new cylinder A is provided in a horizontal position. The piston B forces the rod and finger C against the line-space handle. A heavy base D is provided with leveling screws E for vertical adjustment.

The motion of the line-space handle is recorded by attaching a piece of silk cord to it and running it around the large pulley F. This pulley is very light and is mounted on a small shaft. A fine cord wound on this shaft connects to the arm of the displacement mirror previously described.

Records were first taken on each make of machine when the line space was operated by a typist. From these records the time taken to complete the operation was measured as 0.0363

Work Required to Operate Carriage Return

The apparatus and method for determining the work to operate the carriage return were the same as for the line space. The stops were set to allow a motion of 66 spaces to represent a fairly long line. As the pressure was constant during the stroke it was assumed that the work required for shorter lines would be less in proportion to the length.

The records of Fig. 17 show some curves of carriage motion, and bring out clearly the relatively low velocity attained. The average operator's time for the carriage return of 66 spaces was 0.332 sec.

The data obtained and the computed values are summarized in Table 1. The calculations are based upon a 33-space return in accordance with values to be summarized in a later table.

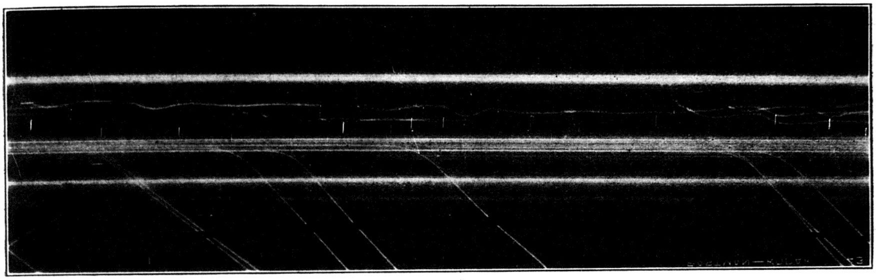


Fig. 16 Line-Space Deflection at Various Pressures
(Upper curves, pressure; lower curves, displacement.)

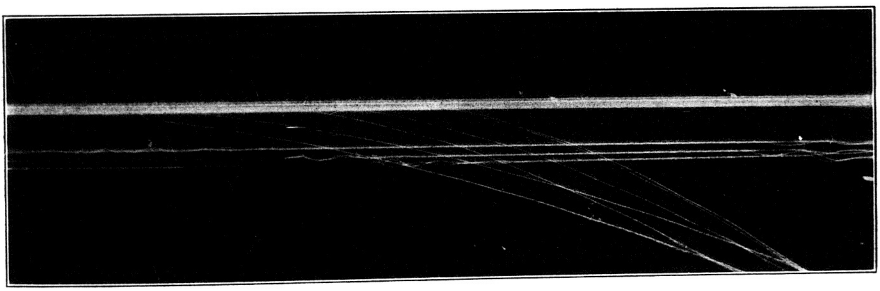


Fig. 17 Carriage-Shift Curves

sec. The roll was then shifted mechanically at several pressures and a curve plotted as previously described for the space bar. In this way the pressure needed to reproduce the motion of the typist was obtained. A number of deflection curves are shown in Fig. 16, the motion being taken in the center of the hook on the line-space lever. The length of stroke was measured as the length of piston travel while the finger was in contact with the key. This was measured at the time of taking the records.

Table 1 gives the results of tests on the roll. The work was computed as before, the piston area being 5.08 sq. cm. and the constant K being again experimentally determined as 0.97.

The work necessary to operate the roll one space is considerably greater than that required to operate the keys. The order of merit of the makes of machines is as follows: D, B, E, C, and A.

The carriage requires a large amount of work for returning. However, a comparatively great uniformity of the values is shown, not only between machines of the same make but between different makes. This is probably due to the fact that the carriage spring tension can be accurately and permanently adjusted. The order of merit for carriage-return work is E, A, C, B, D.

Analysis of Business Letters

Twenty-five letters were selected at random from a set of correspondence files with only the following limitations: (a) no two from the same correspondent, and (b) pica type.

These letters were analyzed by carefully counting the following characteristics of each letter, including the address on the envelope:

(*a*) The number of characters appearing, average 708
(*b*) The number of single spaces, counting no spaces longer than two consecutive single spaces, average 119
(*c*) The number of times the capital shift had been operated, average 38
(*d*) The number of single-spaced lines between the beginning and end of the letter, counting all untyped lines (for the roll motion), average 38
(*e*) The number of lines actually typed (for the carriage motion), average 25.

It is not claimed that the averages obtained here would be duplicated by selecting a second lot of 25 letters, but it is believed that the deviation would be so small that the additional labor involved in obtaining a more representative average would not be justified. At any rate the same figures are used for all makes of machines so that their comparison is not affected.

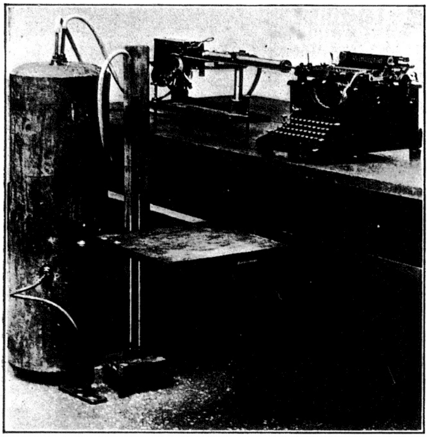


Fig. 18 Apparatus for Moving Carriage

Total Work Required to Write the Average Letter

The sum of the amounts of work required for every operation on the typewriter multiplied by the number of times that the operation occurs in the average letter will give the total work used in writing the letter. These values are given in Table 2.

TABLE 2 TOTAL WORK TO TYPE AVERAGE LETTER[1]

Make	Type keys: Rubber platen	Type keys: Special uniform platen	Space bar	Shift key	Line space	Carriage return	Total work: Rubber platen	Total work: Special uniform platen
	39	28	4	6	16	26	91	80
	30	22	6	6	21	38	101	93
A	32	27	6	5	24	32	99	94
	32	25	6	5	23	32	98	91
	35	27	4	5	22	33	99	91
Average	33.6	26.2	5.2	5.4	21.2	32.2	98	90
	72	42	3	8	15	34	132	102
	49	38	3	5	12	37	106	95
B	40	30	3	5	13	32	93	83
	54	32	3	5	14	38	114	92
	54	38	3	6	17	29	109	93
Average	53.8	36.0	3.0	5.8	14.1	34.0	111	93
	54	34	3	4	18	24	103	83
	40	30	3	4	11	34	92	81
C	40	34	4	3	18	40	105	99
	38	28	5	4	21	30	98	88
	40	32	4	4	21	34	103	95
Average	42.4	31.6	3.8	3.8	17.8	32.4	100	89
	54	38	4	6	10	32	106	90
	42	30	3	4	7	33	89	77
D	44	28	4	4	11	38	101	85
	46	32	3	4	15	37	105	91
	40	32	4	3	11	39	97	89
Average	45.2	32.0	3.6	4.2	10.8	35.8	100	87
	28	25	2	4	14	24	72	69
	32	25	3	4	11	26	76	69
E	28	23	3	4	20	30	85	80
	34	28	3	4	21	26	88	82
	27	21	3	5	18	30	83	77
Average	29.8	24.5	2.8	4.8	16.8	27.2	81	76

[1] All figures in this table should be multiplied by 10,000,000 to give work in ergs.

Precision of Results

We may consider the precision of the work measurements both for the individual components and for the total. If we were interested only in the total work required to write the average letter, no component need be determined any closer than the one of least precision. An examination of the work shows that a majority of the total is made up of the type-key work and the carriage-return work. Therefore the remaining components need be determined with relatively less precision as their effect on the total is small.

However, as it was believed that considerable information could be obtained by a direct comparison of the separate components, they were all obtained with about the same percentage of accuracy.

The work of the type keys was obtained with a precision of ± 5 per cent; that is, different tests under the same conditions could be checked within this amount. The other components had a precision of from ± 3 to 5 per cent. The total work for the average letter should have a probable error somewhat less than that for each component, or around ± 3 per cent.

Conclusions and Recommendations

These tests bring out strikingly the fact that a comparative test made on a single machine of each make would be entirely misleading. Undoubtedly an average of, say, ten machines would give a more representative set of values, but it would be rather unlikely that the relative order of the makes would be changed except possibly in the case of machines C and D.

The marked variability of the work required for different machines of the same make is rather surprising, and brings out clearly the lack of uniformity of adjustment. Again, some makes of machine will require the least amount of work for one of the operations, but no single make holds the advantage in all. If we select the least value for the work of each separate operation in Table 2 and add them, we obtain the figure 64, which is about 0.6 of the average value found for all machines. This brings out the practicability of greatly reducing the work required to write a letter.

The tests indicate clearly that every typewriter of each make should have a standardized factory adjustment. This adjustment should be carefully determined from a thorough study of the machine; and it should give the best compromise between ease of operation, speed, and durability. The typist should be given a machine adjusted for the most efficient operation, and this adjustment should not be changed because of individual inclinations. This would have the distinct advantage of operating under conditions of maximum efficiency and would allow a change from one machine to another without discomfort or extensive servicing. The local adjusters should be permitted only to check the factory adjustment, but not to alter it. In this way all machines would have the same operating characteristics—the best. This program could not perhaps be carried through abruptly, but should start in the schools and in a few years cover all machines used.

There is another aspect of this problem that should not be forgotten. This is the well-recognized physiological fact that work accomplished does not measure effort or fatigue, as a few examples will show. As indicated in Table 2, the work expended

on the keys is about equal to the work expended in returning the carriage, for the average letter; yet nearly every one will admit that it is more tiring to strike the keys 700 times than to move carriage 24 times. Again, the total work needed to type a letter is the same as the amount that would be required for the average person to step up one step on the stairs; and it is needless to say that the typing of 20 letters takes more physical effort than climbing one flight of stairs. This discrepancy between work accomplished and fatigue is mainly due to two things: the muscles not only expend their energy in performing external work, but also perform work in moving the parts of the body, such as the hands and fingers; and the more powerful muscles of the body perform a given amount of work with less fatigue than the weaker ones. This all leads to the conclusion that the work required to operate a typewriter is not an exact measure of physical effort. In the present tests, however, the operation on the different makes are so nearly alike that for comparative purposes the data given should be satisfactory from the point of view of fatigue as well as of work.

Acknowledgment

Practically all of the laboratory work for this investigation was carried out by Prof. L. H. Young of the Department of Physics at the Massachusetts Institute of Technology. The precision attained in these measurements is due to his careful and painstaking work in setting up and operating the special recording instruments used in this investigation.

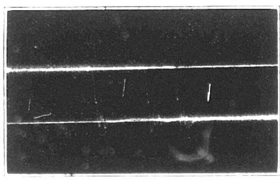


Fig. 2. [illegible]

FIG. 4.—ASSEMBLY FOR OBTAINING OPERATOR'S CURVE.

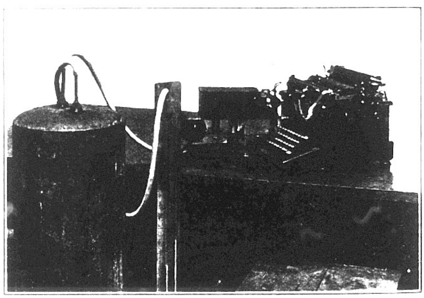
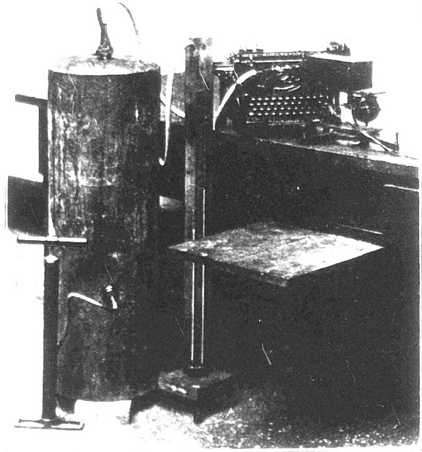
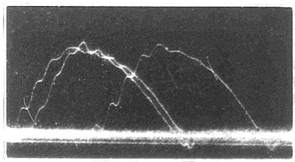
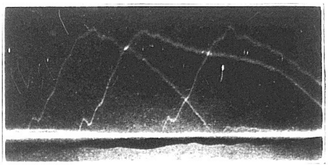
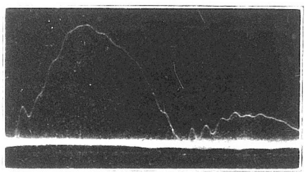


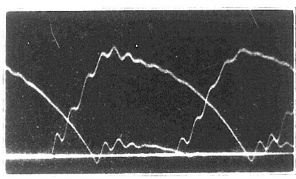
FIG. [illegible].—ASSEMBLY FOR [illegible] OPERATOR'S CURVE.

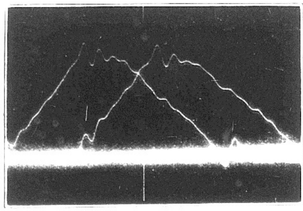


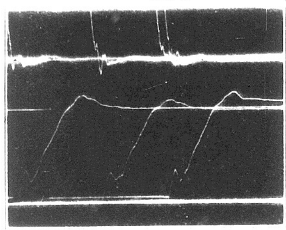


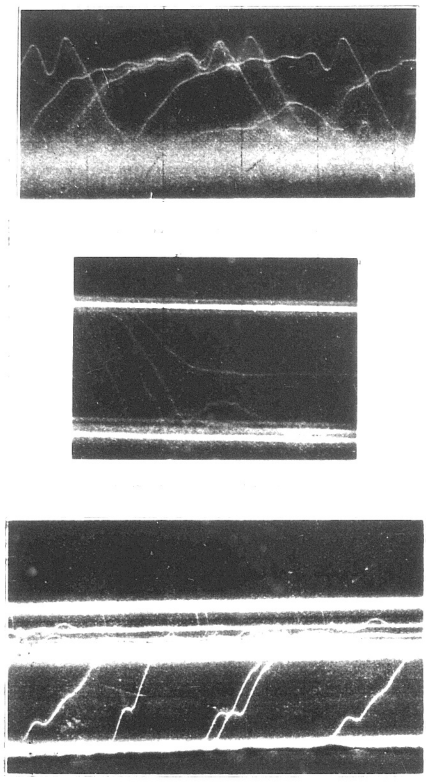


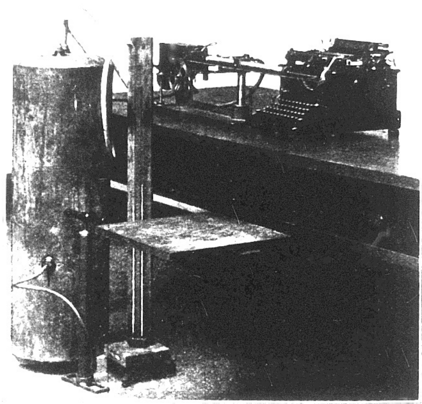


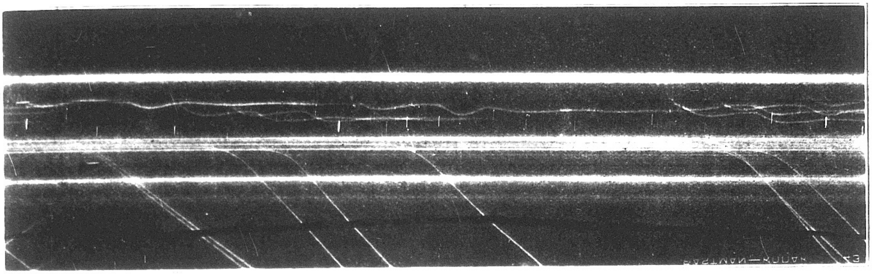


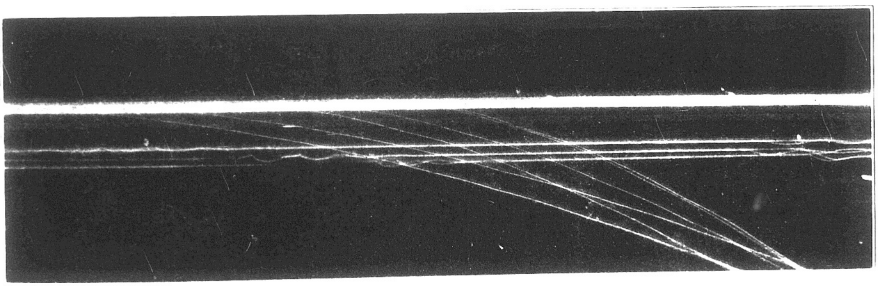












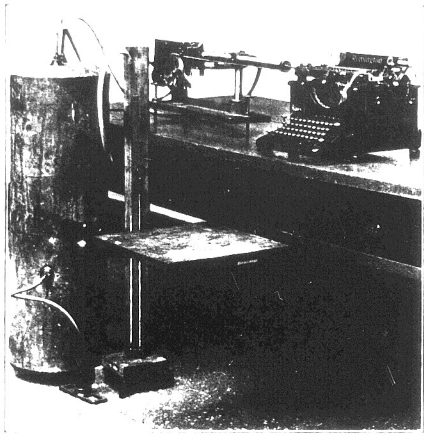


Fig. 18. Apparatus for Moving Carriage